HIGH CURRENT, VERY WIDE BAND TRANSCONDUCTANCE AMPLIFIER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to transconductance amplifiers, and more particularly to high current transconductance amplifiers that are stable over a very wide bandwidth.

2. Related Prior Art

Transconductance amplifiers are widely used as a programmable source of current to calibrate meters, transformers, and shunts, in addition to experimental uses requiring a stable source of constant current. Such an amplifier ideally produces a current in a load proportional to an input voltage and maintains that current independent of the load impedance. There is an increasing need to provide calibrations of current transformers, meters, and shunts at current levels up to and even exceeding twenty amps rms at 100 kHz. Although commercial transconductance amplifiers exist which can deliver currents well in excess of twenty amps, they fail to provide such levels of current above just a few kHz. One of the main limitations to the conventional transconductance design approach is the current-sensing resistor, which for practical reasons, must be in the milli-ohm range for currents in the tens of amperes. Low-value shunt resistors of this order must be of special design to minimize reactance, deviation of resistance with frequency, and temperature effects of resistance.

Prior art has described a variety of fixed and controlled current sources implemented by combinations of monolithic and discrete components. Almost all transconductance amplifier designs or current sources rely on some type of current shunt to provide a voltage proportional to current which is used as feedback to compare it with an input voltage. The shunt must be properly designed to provide a voltage drop across it that is a true measure of the current through it over a wide frequency range with minimum phase shift. At low currents, rather ordinary commercial metal film resistors serve well. However, practical considerations dictate a low-value resistance shunt for high currents. Typically, a resistance of about five to ten milli-ohms is used for current levels in the twenty amp range. Low-value shunt resistors of this order must be of special design to minimize their reactance, deviation of resistance with frequency, and temperature coefficient of resistance. Although good low-value shunt resistors are achievable, they are often proprietary items and expensive because of the special design necessary.

SUMMARY OF THE INVENTION

The present invention overcomes current/frequency limitations by utilizing the inherent tendency for paralleled current mirrors to add currents so that the sum is independent of frequency, thus obviating the need for a single low-resistance high quality current shunt. The input and output of complementary unipolar current-mirror cells are paralleled. Each cell has a fixed current gain determined by the ratio of two resistors. A differential input voltage to current circuit drives the cell array. The design has the advantage of avoiding the need for a single low resistance current sensing resistor and the attendant problems inherent in such resistors. The present invention includes a modification of the

basic idea of using complementary current sources or current mirrors with an operational amplifier to obtain a bipolar voltage controlled current source. A total of ten positive and ten negative current mirror cells each contribute to provide the total bipolar current at the output. This configuration has several advantages. The controlling device within each cell operates at one tenth the maximum peak output current rather than having a single stage power circuit to control the full output current. The total power is therefore dissipated evenly among the cells, allowing easier thermal management. Also, sharing the current by a number of cells has the main advantage of not requiring a single low-resistance shunt in the output circuit to sense the current. And finally, the bandwidth of the system is independent of the number of paralleled cells. Thus, the present invention overcomes the present current/frequency limitation and allows current calibrations to be made over a much broader range.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a transconductance amplifier using paralleled current mirror cells.

FIG. **2** is a schematic diagram of the voltage to current converter of FIG. **1**.

FIG. **3** is a schematic diagram of a positive current mirror cell of FIG. **1**.

FIG. **4** is a graphical representation of simulated time domain current waveforms.

FIG. **5** is a graphical representation of a simulated output impedance of a cell as a function of frequency.

FIG. **6** is a graphical representation of the pulse response of the transconductance amplifier of FIG. **1**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A simplified diagram of a cell-based transconductance amplifier **12** is illustrated in FIG. **1**. A total of ten positive current mirror cells, **14A–14G**, connected in parallel, and ten negative current mirror cells, **16A–16G**, also connected in parallel, each contribute to provide the total bipolar current at output **18** to load **20**. The current gain of each cell is determined by the ratio of two resistors, resistors **44** and **50**, (see FIG. **3**). A differential voltage to current converter **22** converts an input voltage across terminals **24** to a current that is separated for polarity and steered to the appropriate cell array. This invention differs from prior art in several respects. The paralleled cell approach of the present invention has the advantage of avoiding the need for a special low resistance current shunt and the problems inherent in providing such resistors. The present invention employs inexpensive commercially available resistors in each cell. The overall gain is independent of the number of paralleled cells but the output current capability increases proportionally while the bandwidth remains independent of the number of cells. The overall gain of the transconductance amplifier can be ranged by a single resistor change which does not affect the bandwidth. The present invention has the flexibility to make a very wide ranging transconductance amplifier by switching in or out the appropriate number of current cells depending on the required maximum output current.

A primary application for transconductance amplifier **12** of the present invention is for calibrating high current, wide band current shunts as well as new current